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REVIEW OF SURFACE COAL MINING EMISSION FACTORS

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PREFACE

This interim report was prepared by Midwest Research Institute under U.S. Environmental Protection Agency (EPA) Contract No. 68-DO-0137, Work Assignment No. 10. The principal author of this report is Dr. Greg Muleski; he was assisted by Mr. Robert Dobson and Ms. Karen Connery. Mr. Dennis Shipman of the Office of Air Quality Planning and Standards serves as the EPA's technical monitor of the work assignment.

Approved:

for Charles F. Holt, Ph.D., Director
Engineering and Environmental
Technology Department

July 11, 1991

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SECTION 1

INTRODUCTION

As part of the Clean Air Act Amendments of 1990, the U.S. Environmental Protection Agency has the need to review and revise emission factors for criteria pollutants. Specifically, Section 234 of Title I requires field testing for emission factors for surface coal mines. This interim report provides a review of currently available, field-measurement-based emission **factors** for surface coal mines (SCMs) and describes field testing needs to address gaps in the data base.

A principal purpose of the review is to provide a common basis for discussion at a workshop to be held in Kansas City, Missouri, during August 1991. This report has been sent to interested parties who have been invited to participate at the workshop. These parties include coal and mining industry groups, environmental organizations, and state and federal agencies for mining activities and environmental protection.

Throughout the report, the review focuses on the strengths and weaknesses of the available data, thus identifying major gaps within the data base.

The remainder of this report is structured as follows. Section 2 presents a brief overview of the surface coal mining industry. Section 3 describes the types of emission sources found at SCMs, emphasizing operating characteristics that are potentially different between various parts of the country. In Section 4, the methods available to estimate emissions from SCM sources are discussed and major gaps within the data base are identified. Section 5 summarizes the results of the review and presents a series of recommendations. Section 6 lists the references cited in the report.

Emission factors relate the amount of mass emitted per unit activity of the source. For example, a common unit for travel related emissions is "lb/vmt," or pounds emitted per vehicle mile traveled. Thus, the "source extent" on a road is measured in terms of the total miles traveled by vehicles over the road. Similarly, if a material handling emission factor is expressed in terms of pounds emitted per ton (or, cubic yard), then the source extent is measured in terms of the tons or cubic yards of material transferred.

The following discussion uses English-such as pounds and miles--rather than metric (SI) units-such as kilograms and kilometers. This approach has been taken because it is believed that individuals taking part in the Kansas City workshop will be more familiar with common English units.

The principal pollutant of interest in this report is "particulate matter" (PM), with special emphasis placed on "PM-10"—particulate matter no greater than 10 μmA (microns in aerodynamic diameter). PM-10 is the basis for the current National Ambient Air Quality Standards (NAAQSs) for particulate matter as well as the EPA's Prevention of Significant Deterioration (PSD) increments.

PM-10 thus represents the size range of particulate matter that is of the greatest regulatory interest. Nevertheless, formal establishment of PM-10 as the standard basis is relatively recent, and virtually all surface coal mine field measurements reflect a particulate size other than PM-10. Other size ranges employed in this report are:

TSP Total Suspended Particulate, as measured by the standard high-volume (hi-vol) air sampler. TSP was the basis for the previous NAAQSs and PSD increments. TSP is a relatively coarse size fraction. While the capture characteristics of the hi-vol sampler are dependent upon approach wind velocity, the effective D50 (i.e., 50% of the particles are captured and 50% are not) varies roughly from 25 to 50 μmA.

SP Suspended Particulate, which is used as a surrogate for TSP. Defined as PM no greater than 30 μmA. Also denoted as "PM-30."

IP Inhalable Particulate, defined as PM no greater than 15 μmA. Throughout the late 1970s and the early 1980s, it was clear thaf EPA intended to revise the NAAQSs to reflect a size range finer than TSP. What was nwt clear was the size fraction that would be eventually used, with values between 7 and 15 μmA frequently mentioned. Thus, many field studies at SCMs were conducted using IP measurements because it was believed that would be the basis for the new NAAQS. IP may also be represented by "PM-15."

FP Fine Particulate, defined as PM no greater than 2.5 μmA Also denoted as 'PM-2.5."

it is again emphasized that this is an interim report whose purpose is to provide a common basis for further discussion at the Kansas City workshop. It is probable that several issues in addition to those presented here will be raised at the workshop. This report, then, is an initial focus point for constructive discussions and, in that sense, represents very much a "work in progress."

SECTION 2

OVERVIEW OF THE SURFACE COAL MINING INDUSTRY

Coal is mined in 26 states. The leading coal producers are Kentucky, Wyoming, West Virginia, Pennsylvania, Illinois, Texas, Virginia, and Ohio; these states account for approximately 75% of U.S. coal production.[1]

United States coal reserves total approximately 490 billion tons. Of that total, 330 billion tons are estimated to be minable by underground methods and 160 billion tons by surface methods. Since the early 1970s surface mines have accounted for more than half of the total coal produced. In 1985 coal was produced by both underground and surface mining in 15 of the 26 coal-producing states, with the remaining 11 having surface mines only.

For discussion purposes in this report, the U.S. coal mining industry has been divided into three major regions:

- Appalachian Region
  - Northern Appalachia
  - Central Appalachia
  - Southern Appalachia
- Midwest Region
- West Region
  - Powder River
  - Rocky Mountain

(The small amount of coal mining in Alaska is not considered in this report.) Each region and subregion is briefly described in the following paragraphs.[2]

Northern Appalachia includes the states of Maryland, Pennsylvania, Ohio, and northern West Virginia. Coal production is largely high to medium sulfur bituminous coal. Eastern Pennsylvania is home to the only working anthracite mines in the United States. Bituminous coal production in the Northern Appalachian Region totaled 155.5 million tons in 1985 of which 62.2 million tons were surface mined and 93.4 were mined using underground methods (see Figure 1). Northern Appalachia is characterized by a small number of underground mines and a large number of very small surface operations.

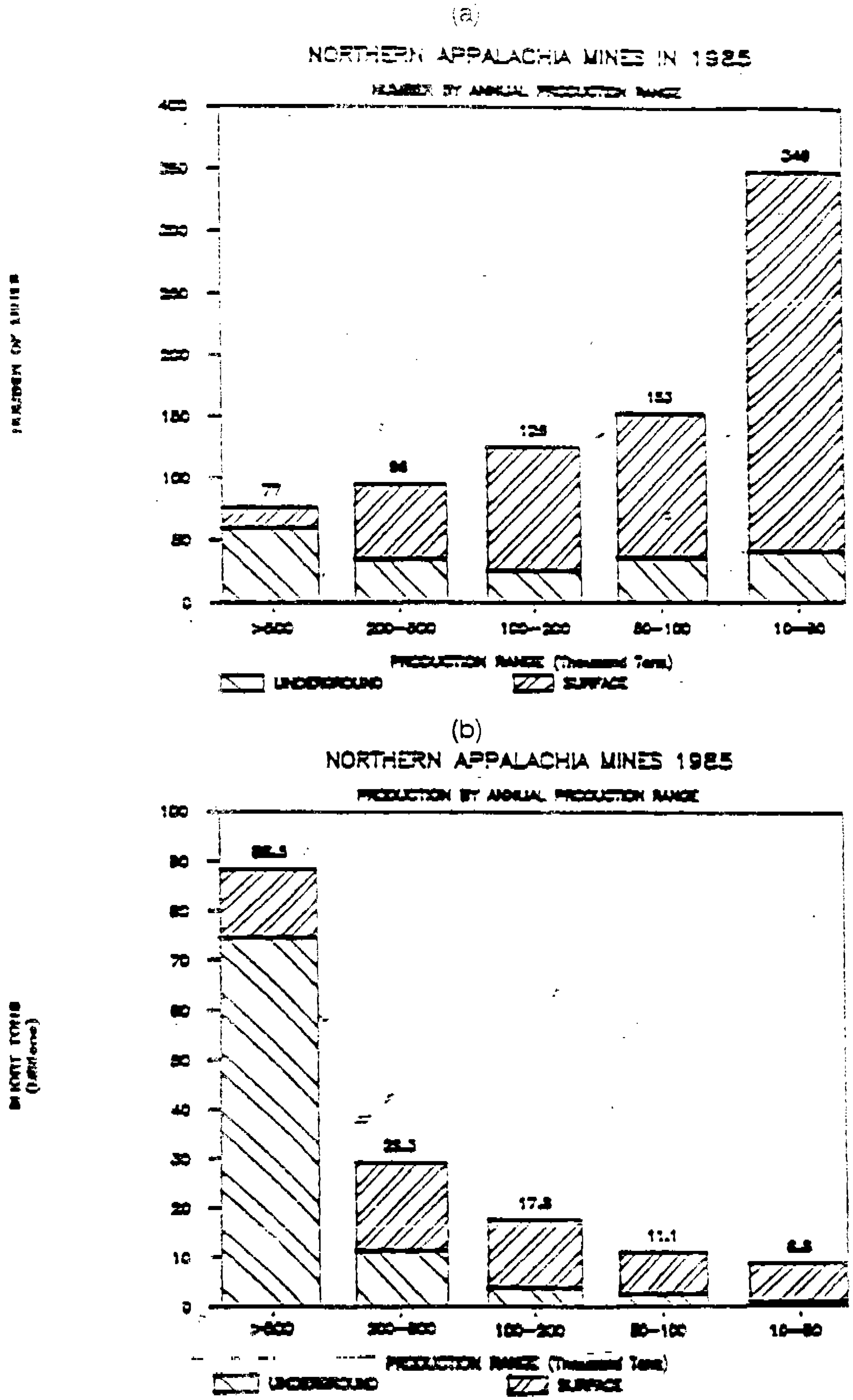


Figure 1. Histograms showing (a) number of mines and (b) total annual production as a function of mine size for the Northern Appalachia Region in 1985. From Reference 3.

Central Appalachia includes areas in Southern West Virginia, Virginia, the eastern half of Kentucky, and Northern Tennessee. The coal reserve base is approximately 52 billion tons of bituminous coal, of which 7.9 billion tons are minable by surface methods and 44.1 billion tons are recoverable by underground methods. Production in 1985 was 232.4 million tons of which 72.1 million tons were surface mined (see Figure 2).

Central Appalachia is characterized by a large number of "mom and pop" surface and underground mines. The mines are termed in this way due to the small, informal, family nature of most of the operations.

Southern Appalachia includes the mining areas of Alabama and southern Tennessee. The reserve base totals 4.9 billion tons of bituminous coal split equally between surface and underground mining methods. A l-billion ton reserve of lignite is not presently mined. Production of bituminous coal in Southern Appalachia totaled 30.1 million tons in 1985 of which 13.9 million tons were surface mined. Southern Appalachia is characterized by a few producers with large capacity underground mines, and medium to small surface mines (see Figure 3).

The Midwest Region includes regions of Illinois, Indiana, and western Kentucky and is also known as the Illinois Coal Basin. The entire 110 billion ton reserve base is bituminous. Of this total, 21 billion tons are surface minable. Coal production in the Midwest totaled 131.4 million tons in 1985 (74.1 million tons surface mined).

The Midwest Region is characterized by large corporate mines. This is particularly true of underground mines. As shown in Figure 4, Midwest surface mines are quite uniformly distributed over a very broad range of annual production values.

Western coal mining is divided into two areas, the Rocky Mountain Region and the Powder River Basin. The Powder River Basin includes Montana and Wyoming. The reserve base ranges from lignite to reasonably high quality bituminous. The total reserve base is 189.4 billion tons, of which 168 billion tons is classified as subbituminous, 16 billion tons as lignite, and 6 billion tons as bituminous. Production in the Powder River Basin totaled 174 million tons in 1985, virtually all of which was surface mined (Figure 5). The Powder River Basin is characterized by very large surface mines, with the largest mines in the United States in this region.

The Rocky Mountain Region includes the states of Colorado, Utah, New Mexico, and Arizona. This region has reserves in four different classifications: anthracite, bituminous, subbituminous, and lignite, Recoverable reserves total 18.5 billion tons, of which 8 billion tons are considered minable by surface methods.

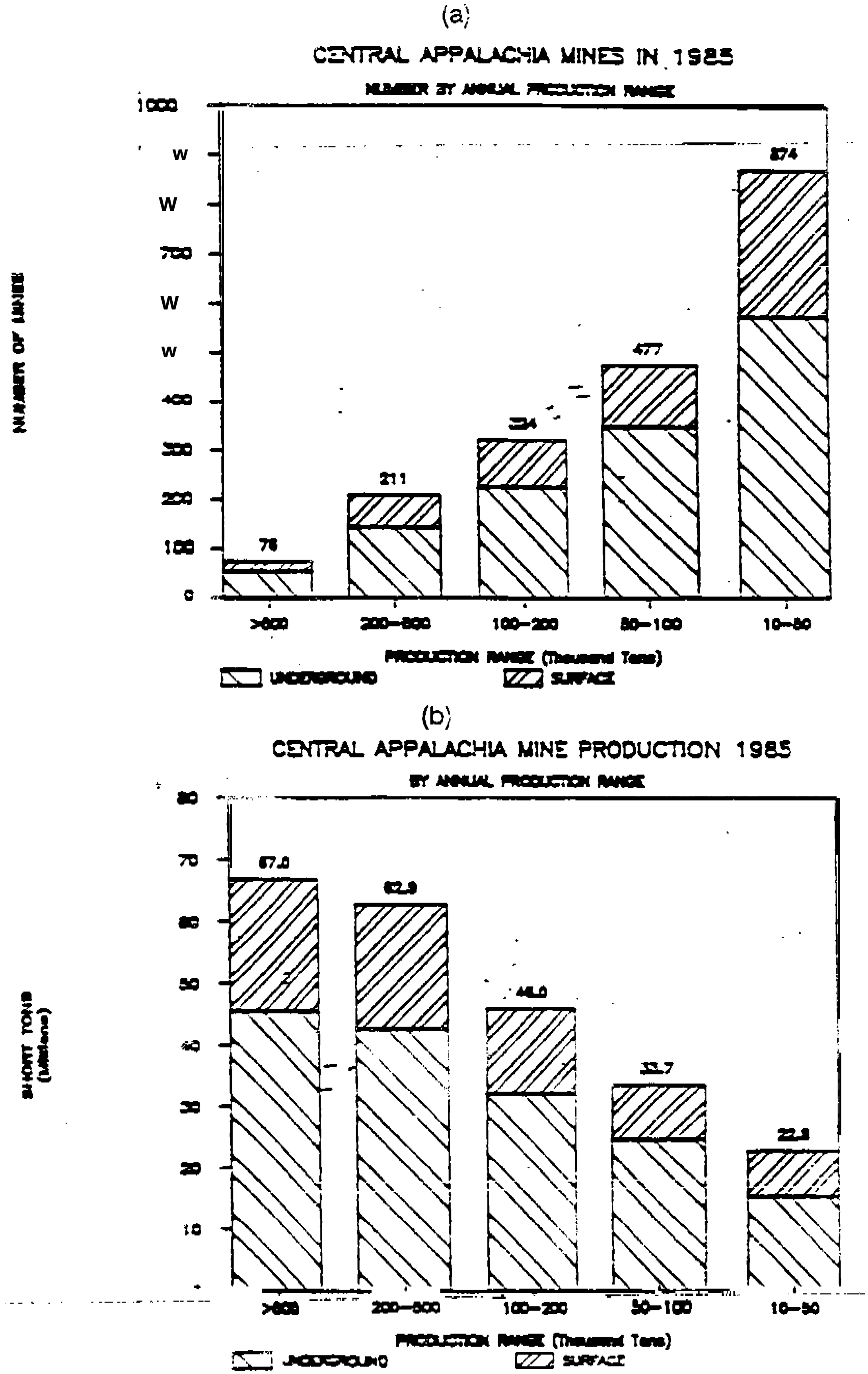


Figure 2. **Histograms showing (a) number of mines and (b) total annual production as a function of mine size for the Central Appalachia Region in 1985. From Reference 3.**

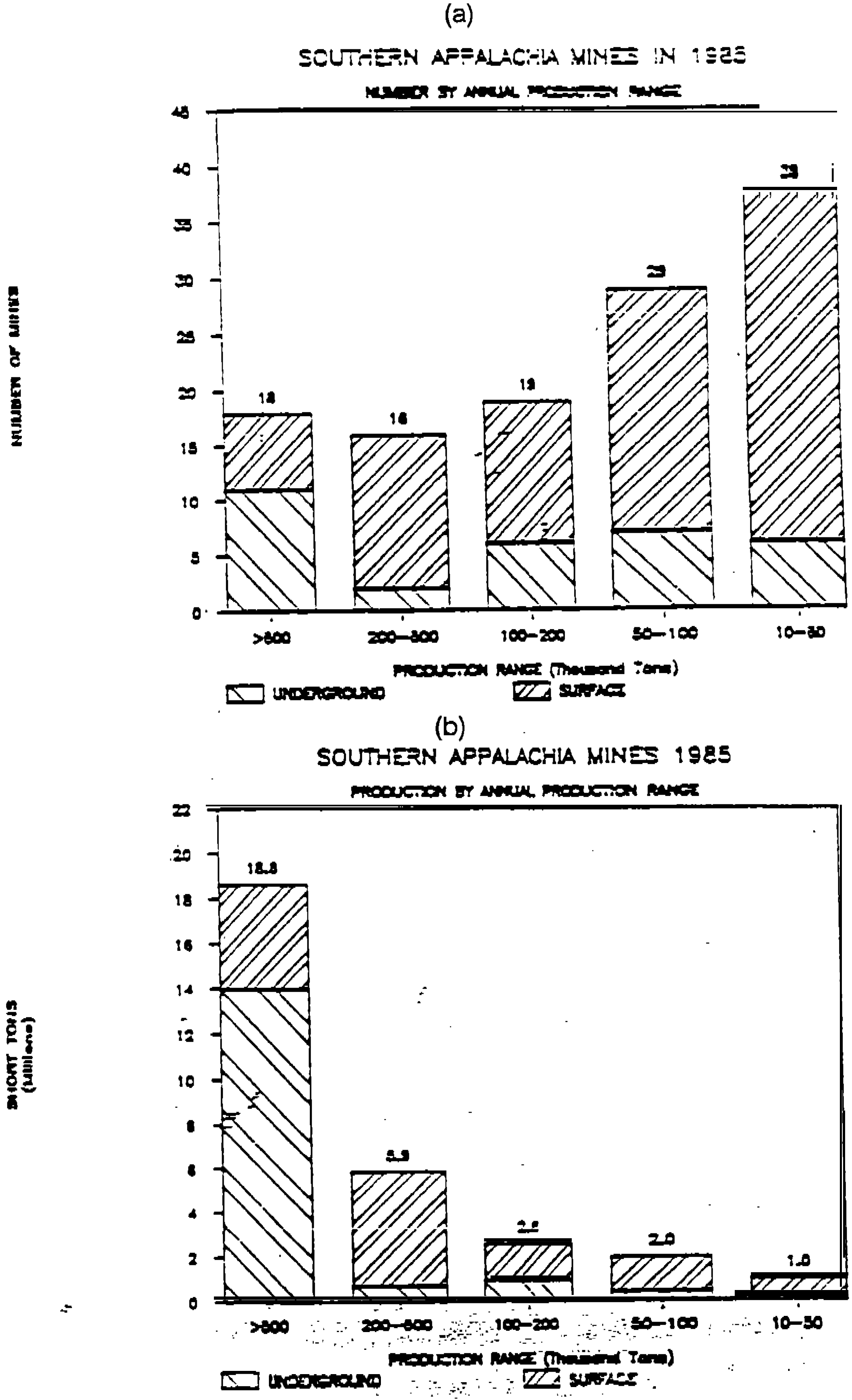
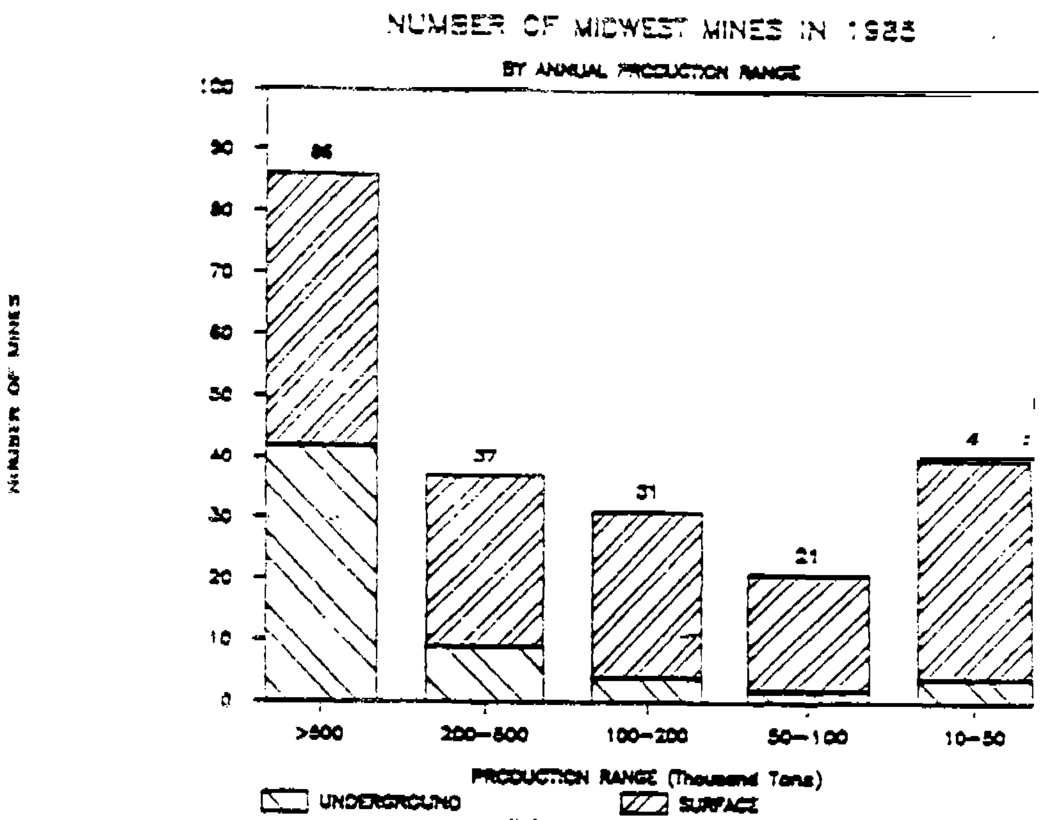


Figure 3. **Histograms showing (a) number of mines and (b) total annual production as a function of mine size for the Southern Appalachia Region in 1985. From Reference 3.**

(a)



(b)

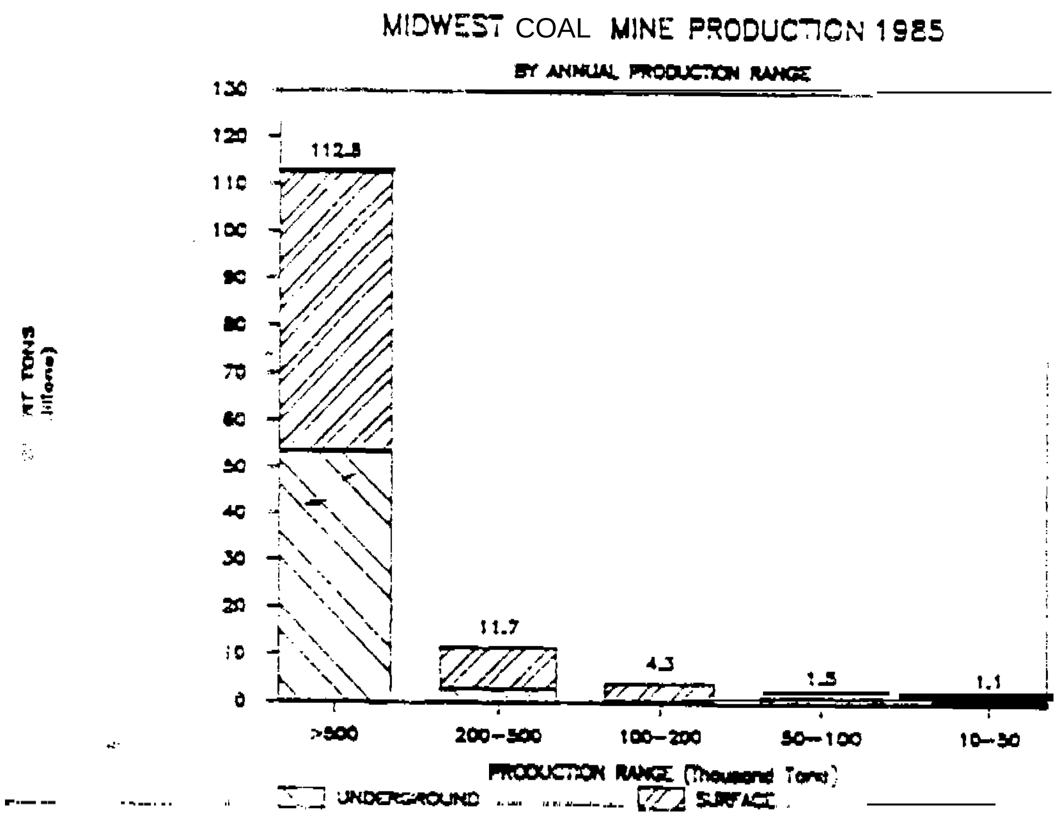


Figure 4. Histograms showing (a) number of mines and (b) total annual production as a function of mine size for the Midwest Region in 1985. From Reference 3.

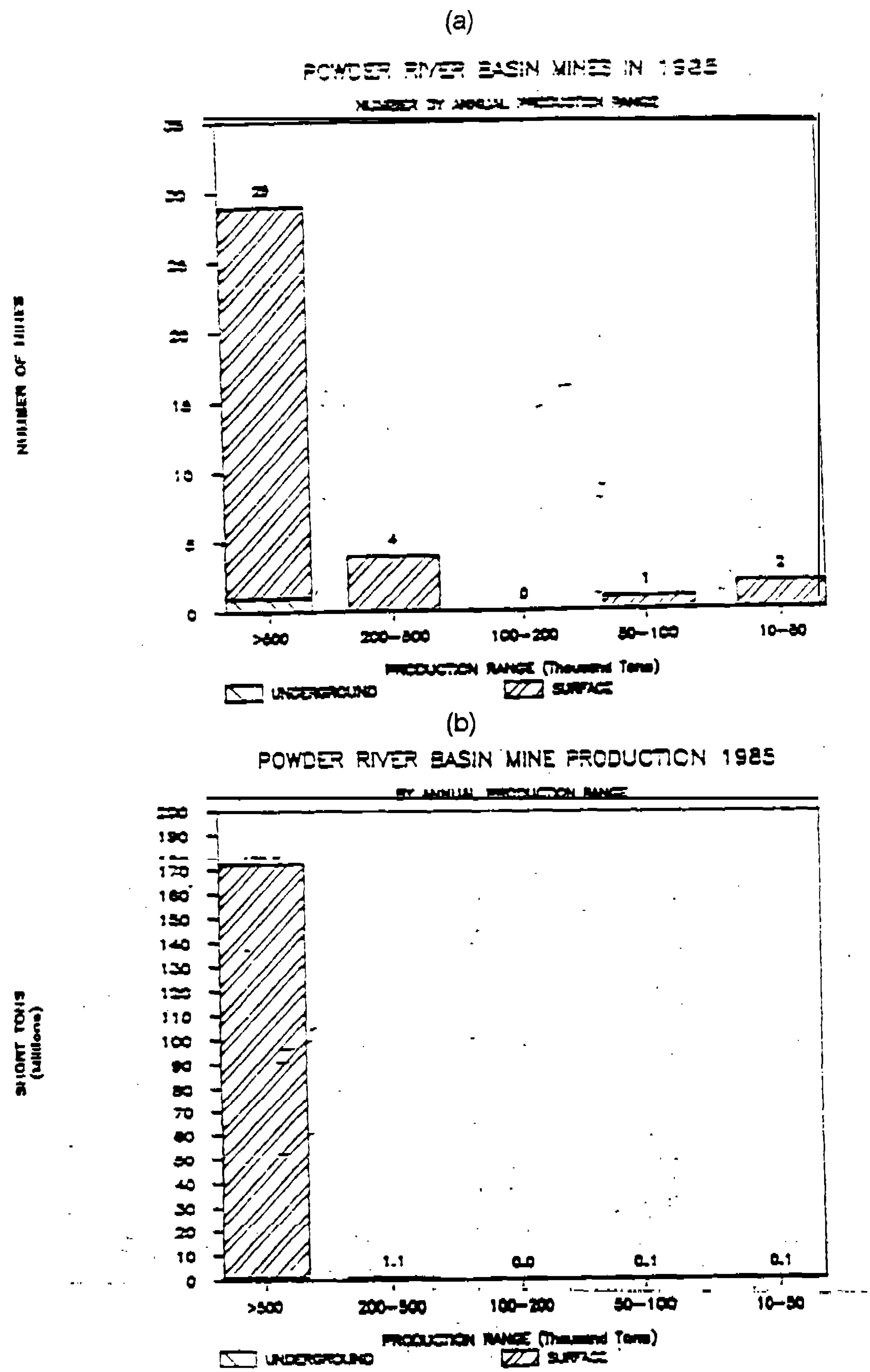


Figure 5. Histograms showing (a) number of mines and (b) total annual production as a function of mine size for the Powder River Basin in 1985. From Reference 3.

Coal production in the Rocky Mountain Region totaled 61.9 million tons in 1985 of which 42 million tons were surface mined, The total consisted of bituminous and subbituminous coal. Large surface operations and large underground operations characterize the region (see Figure 6).

Tables 1 and 2 provide summary information for the 1985 United States coal production in the Appalachian/Midwest and West regions, respectively.

In summary, the number of mines increases and the average size decreases as one considers U.S. surface coal mines from east to west. The Appalachian Region has many small surface operations while the relatively few western mines are almost all very large. The Midwest Region represents the transition between the two extremes, with surface mines in all size ranges relatively common.

Approximately 50% of the coal surface mined in the United States is from eastern regions, where mines tend to be relatively small. As will be seen in the next section, emissions from eastern SCMs have not been considered to any great extent. Consequently, potential differences in PM emissions due not only to the different size of mines, but also different climate factors in the east, have not been fully characterized.

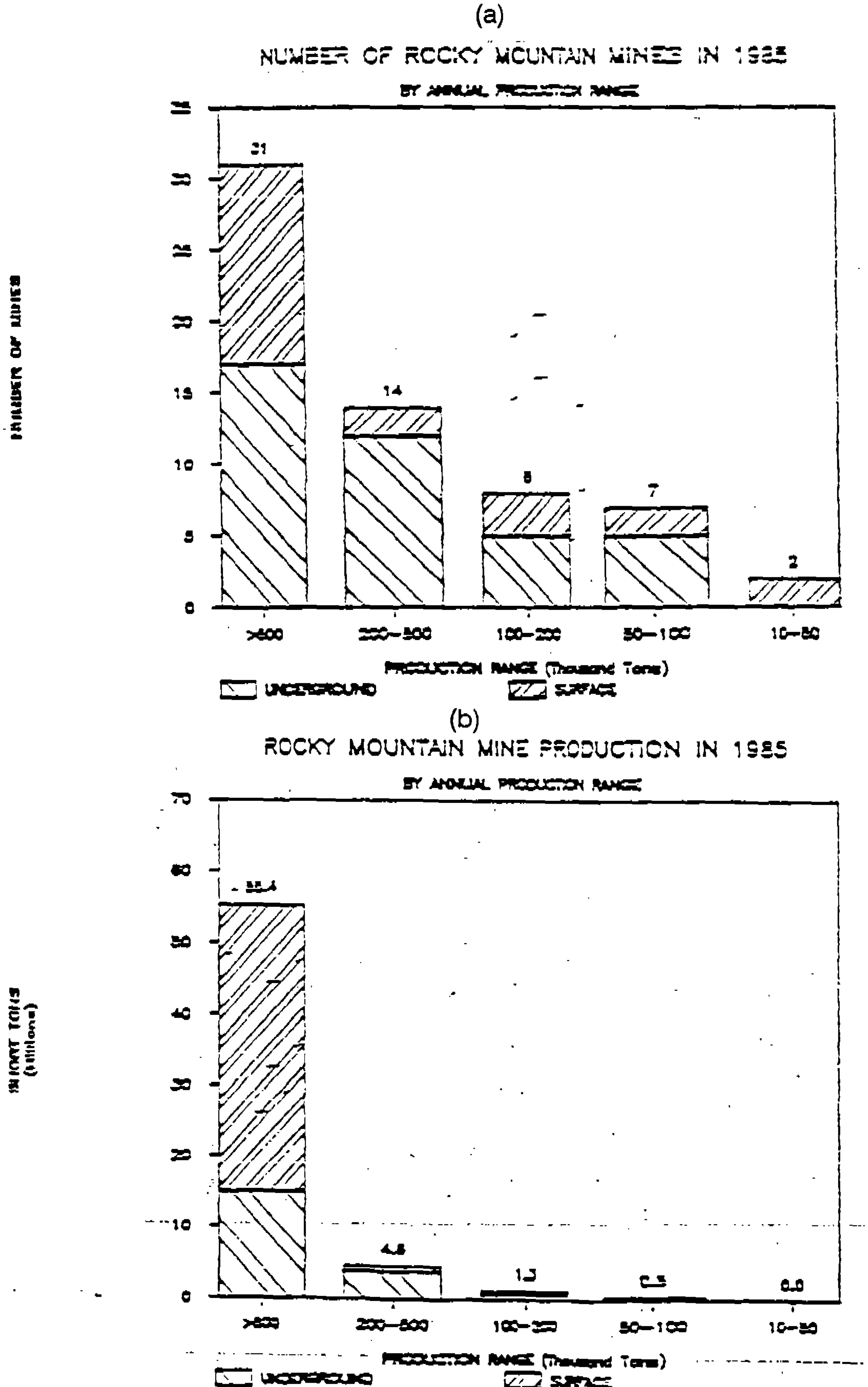


Figure 6. Histograms showing (a) numb& of mines and (b) total annual production as a function of mine size for the Rocky Mountain Region in 1985. From Reference 3.

Table 1. EASTERN AND MIDWESTERN UNITED STATES COAL PRODUCTION STATISTICS

	Eastern coal production (tons x 10^3)					Ave. mine size (tons/yr)	
Region	Total	Underground	Percent of total (%)	Surface	Percent of total (%)	Underground	Surface
Northern Appalachia	155,532	93,367	60.0	62,165	40.0	472,000	103,000
Central Appalachia	232,380	160,296	69.0	72,083	31.0	127,000	108,000
Southern Appalachia	30,122	16,233	53.9	13,889	46.1	507,000	158,000
Midwest	131,415	57,303	43.6	74,112	56.4	939,000	481,000
Pennsylvania Anthracite	4,281	440	10.3	3,841	89.7	49,000	55,000
Totals	553,730	327,639	59.2	226,091	40.8	--	--

Table 2. WESTERN UNITED STATES COAL PRODUCTION STATISTICS

	Western coal production (tons x 10³)					Ave. mine size (tons/yr)	
Region	Total	Underground	Percent of total (%)	Surface	Percent of total	Underground	Surface
Rocky Mountain	61,876	19,925	32.2	41,951	67.8	510,000	1,824,000
Powder River Basin	173,997	1,058	0.6	172,939	99.4	1,058,000	4,941,000
Totals	235,873	20,983	8.8	214,890	91.2	--	--

SECTION 3

OVERVIEW OF EMISSION SOURCES AND MEASUREMENTS AT SURFACE COAL MINES

Throughout the surface mining process-from initial removal of topsoil until final reclamation-particulate matter (PM) may be emitted from a variety of operations. This section (a) discusses major PM emission sources at surface coal mines and (b) provides a short history of field measurement of those emission sources.

IMPORTANT EMISSION SOURCES

Table 3 summarizes particulate matter emission sources typically found at surface coal mines; the operations listed in the table are largely sequential. All sources may be present simultaneously throughout different areas at any one mine.

Clearly, PM sources vary in importance not only from one mine to another-depending on, say, strip ratios or the type of equipment used (power shovel, dragline, bucket wheel excavator [BWE])-but also from one time to another at the same mine-for example, when haul distances and hence haulage-related emissions are the greatest.

Several prior studies have examined, in general terms, the relative importance of different emission sources at SCMs. Inventories of hypothetical examples as well as of actual mines indicate that typically over half (roughly 60% to 90%) of the total suspended particulate (TSP) emission rate is due to the following four traffic-related sources:

- scraper travel
- coal haul trucks
- overburden haul trucks
- general (light and medium duty) traffic

Not all of the four sources are necessarily important at every mine. For example, overburden haul trucks are not used at a dragline mine; in that case, overburden removal by dragline becomes far more important. Also, general traffic might not be important at, say, small mines with deep coal seams.

Table 3. SUMMARY OF MAJOR EMISSION SOURCES AT SURFACE COAL MINES

Topsoil related activities
- Removal
- Scraper travel
- Material handling and storage activities
- Replacement

Overburden related activities
- Drilling
- Blasting
- Removal
- Truck haulage
- Material handling and storage activities
- Replacement
- Dozer activity

Coal seam activities
- Drilling
- Blasting
- Loading
- Truck haulage
- Truck unloading
- Processing (crushing, screening, etc.)
- Material handling and storage activities
- Dozer activity
- Loadout for transit

General activities
- Vehicle travel
- Road grading
- Wind erosion of open areas and materials in storage

In very general terms, the four traffic-related sources listed above plus overburden removal by dragline should account for roughly 70% of total TSP emissions at most large surface mines.[3]

FIELD MEASUREMENTS AT SURFACE COAL MINES

Since 1973, production in U.S. western mines has more than tripled.[1,2] The expansion is in large part the result of events during the early 1970s: the original Clean Air Act resulted in high demand for low-sulfur western coals, and the 1973 oil embargo stressed the importance of energy independence and spurred mining activities. Thus, the development of large western SCMs was accompanied by a more widespread interest in protecting the environment.

It is not surprising, then, that essentially all of the available field measurement data base (a) dates from the late 1970s and early 1980s and (b) primarily reflects western SCMs. Consequently, two limitations of available data become immediately apparent:

1. Eastern surface coal mines may not be well characterized in terms of emission characteristics. Recall that these mines tend to be substantially smaller in terms of production and disturbed area. In addition, there has long been a suspicion that open dust emission levels differ substantially between the eastern and western United States. This point is discussed further in the next section.

2. Throughout the country, available field measurements generally do not reference the particle size range of current regulatory interest, because of the relatively recent emergence of PM-1 0 as the basis for the PM NAAQSs. Furthermore, some field measurements have been found to be unreliable in terms of particle size characterization. This, too, is discussed in Section 4.0.

Table 4 summarizes major field measurement studies undertaken to determine emission factors generally applicable for SCMs.[5-8] Note that only two of the test programs considered mines east of the Mississippi River. The PEDCo/MRI study forms the principal basis for EPA's recommended emission factors for western surface coal. These factors are included in Section 8.24 of the EPA publication "Compilation of Air Pollutant Emission Factors," commonly referred to as "AP-42."[9]

Throughout the next section, it is assumed that the reader is familiar with common open dust source measurement techniques such as "upwind/ downwind" and "exposure profiling." Detailed descriptions of open source measurement methodologies are available elsewhere."

Table 4. MAJOR FIELD TESTING PROGRAMS AT SURFACE COAL MINES

Name	Location (fields)	Sources	Comments	Reference No.
EDS Study	Powder River	Haul roads coal dump train loading overburden replacement topsoil removal wind erosion.	Emphasis on source depletion, and "apparent emission factors" at various downwind distances; exposure profiling and upwind/ downwind approaches..	5
PEDCo/MRI	Fort Union Powder River San Juan	Coal loading dozers - overburden - coal dragline haul roads general traffic scrapers graders	Combination of exposure profiling and upwind/downwind tests; emission factors developed form the backbone of AP-42 Section 8.24.	6
Skelly & Loy	Logan County., West Virginia	D/OR/CL[a] graders haul roads	Upwind/downwind sampling over 1 O-day period; screening-type study.	7
PEDCo/ BuMines	Southern Illinois Southwestern Wyoming Northeastern Wyoming	Haul roads	Exposure profiling with stacked filtration units (SFUs); emphasis on haul road dust control efficiencies; no attempt made to develop general emission factor models.	8

[a] Drilling, overburden replacement and coal loading treated as a single emission source.

The EDS study was conducted to develop PM emission factors for primary surface mining activities. Two mines in the Powder River Basin were considered, with tests conducted between fall 1978 and summer 1979. Emission factors are presented for the following sources:

trucks hauling coal or overburden (with and without watering as a control measure)

coal dumping

train loading

overburden replacement

topsoil removal by scrapers

wind erosion of stripped overburden and reclaimed land

With the exception of haul trucks, emissions were characterized using an upwind/downwind approach; haul truck tests employed exposure profiling. Results are summarized in Table 5. TSP was the particle size range of interest.

This industry-sponsored program paid particular attention to particle deposition and its implications for dispersion modeling. Emission factors are presented not only for at-source conditions, and "apparent" factors are given for distances of 500 and 1,000 m. At-source emission factors have largely been incorporated into AP-42 Section 8.24.

The PEDCo/MRI study was conducted with the express goal of developing emission factor equations for western SCM operations. TSP, IP, SP, and FP were the size ranges of interest. Three mines-in the Fort Union, the Powder River, and the San Juan Fields-were considered over the summer and fall of 1979 and the summer of 1980.

A combination of the exposure profiling, upwind/downwind, and portable wind tunnel sampling methodologies were employed to characterize emissions from the sources listed in Table 6, which summarizes the upwind/downwind and exposure profiling tests emissions testing conducted. Wind tunnel measurements and wind erosion emission factors are described later.

As noted earlier, this study provides most of the experimental basis for AP-42 Section 8.24.

The Skelly & Loy study, conducted as one part of an EPA contract, is the only field program in Table 4 devoted entirely to eastern surface coal mining.

Table 5. SUMMARY OF EDS[5] RESULTS[a]

Source	Emission factor at source	Apparent emission factor at 500 m	Apparent emission factor at 1.000 m
Haul roads	22.0 lb/VMT	8.5 lb/VMT	7.8 lb/VMT
Coal dump	0.066 lb/ton	0.024 lb/ton	0.022 lb/ton
Train load	0.028 lb/ton	0.010 lb/ton	0.009 lb/ton
Overburden replacement	0.012 lb/ton	0.004 lb/ton	0.004 lb/ton
Topsoil removal	0.058 lb/ton	0.021 lb/ton	0.019 lb/ton
Wind erosion	0.38 ton/acre-year @ 4.7 m/s mean wind speed	not applicable	not applicable

[a] Taken from Reference 11. Size range is TSP.

Table 6. SUMMARY OF EMISSIONS TESTING CONDUCTED BY PEDCo/MRI

Location*	Source	Control (C/U)[b]	No. of tests	Range	Units	Mean	Size
1	Coal loading"		2	0.004-0.031	lb/ton	0.010	TSP
2			8	0.002-0.121		0.025	
3			15	0.005-1.271		0.135	
1	Dozer overburden[c]		4	0.600-22.2	lb/hr	8.0	TSP
2			7	0.000-l 9.8		2.97	
3			4	2.500-25.9		10.4	
1	Dozer coal[c]		4	8.300-50.8	lb/hr	25.2	TSP
2			3	1 .000-13.4		6.3	
3			5	152-670		312	
1	Dragline'		6	0.001-0.446	lb/yd^3	0.069	TSP
2			5	0.000-0.071		0.024	
3			8	0.021-0.246		0.115	
1	Haul roads'		5	1.100-18.4	lb/vmt	8.2	TSP
1W			6	4.50047.8		19.4	
1	Haul trucks'	U	6	12.90-33.0	lb/vmt	19.6	
2			10	0.600-8.2		4.2	
		U	6	3.900-8.2		5.6	
		C	4	0.600-3.4		2.2	
1W		U	3	0.710-73.1		47.0	
3			9	1.800-24.1		10.0	
		U	4	6.300-24.1		16.3	
		C	5	1.800-8.4		5.0	
1	Light-med. duty		5	0.350-0.82	lb/vmt	5.2	
	vehicles	U	3	5.500-8.2		6.8	
		C	2	0.35		0.35	
2		U	4	0.600-0.93		0.73	
3		U	3	7.800-9.0		8.4	
1	Scrapers	U	5	3.900-50.2	lb/vmt	18.0	
2		U	6	1 O-30-74.3		32.9	
1W		U	2	163-355		259	
3		U	2	4.0		4.0	
2	Graders	U	5	1.800-7.3	lb/vmt	4.1	
3		U	2	8.600-34.0		21.3	

a 1 = Fort Union
2 = Powder River Basin
3 = San Juan River Fields
W = Winter tests

b C/U: controlled/uncontrolled.

c Upwind/downwind tests.

Upwind/downwind field measurements were collected over a short, IO-day period to determine TSP emission factors for

haul trucks

drilling/overburden removal/coal loading (considered as one source)

regrading of land where coal had been removed

See Table 7.

The scope and extent of this "screening type" study are much more limited than those for the other programs listed in Table 4. In addition, the authors noted that wind speeds and haul truck travel speeds were substantially higher than in the western studies. Consequently, it is very difficult to interpret the Skelly & Loy emission factors that are roughly an order of magnitude greater than corresponding western results. At the very least, however, this study indicates a need for further characterization of PM emissions at eastern SCMs.

The scope of the PEDCo/BuMines study was much more focused than the other studies in Table 4. While the other programs considered several emission sources, this program was undertaken to determine the efficiency and cost-effectiveness of dust controls applied to SCM haul roads. Tests were conducted at three mines-including one east of the Mississippi—during the summer and fall of 1982. Types of controls considered included: salts, surfactants, adhesives, bitumens, films, and plain water. Table 8 summarizes results of this test program.

Three points should be noted about this study. First, the report states that, because of the emphasis on control efficiencies, there was no attempt made to develop general emission factors for unpaved haul roads

Second, exposure profiling measurements were made using stacked filtration units (SFUs). The SFUs were designed to produce data for the SP and FP size fractions. However, an independent contractor has found that the SFU collection media were selected on the basis of pore size and collection efficiency was not verified through calibration. A 1985 collaborative study of five different exposure profiling systems found that, as samples are collected, SFUs become more efficient. As a consequence, concentration and emission factors are systematically underestimated.[12,13] Overall, the independent evaluation concluded that SFUs could not be recommended for open dust emission characterization.[12] As a result, this independent emissions data base is of little value in judging the "predictive accuracy" of haul road emissions factors

Table 7. SUMMARY OF EMISSIONS TESTING CONDUCTED BY SKELLY & LOY[7]

Operation	Number of samples	TSP emission factor	Units
Drilling/overburden removal/coal loading	33	339.6	lb/workday/acre
Regrading	7	442.2	lb/workday/acre[a]
		54	lb/hr[a]
Haul roads	8	246.8	lb/vehicle mile

[a] Regrading emission factor stated in two sets of units for comparison purposes.

Table 8. EMISSION FACTORS REPORTED BY THE PEDCo/BuMINES STUDY

Location[a]	Control method	No. of tests	Emission factors[b] Range	Emission factors[b] Mean
1	Calcium chloride	6	0.12-4.65	2.00
	Acrylic	12	0.70-6.79	3.42
	Petrotac	2	6.90-10.3	8.64
	Lignon	8	0.79-14.7	6.13
	Water	12	2.02-3.80	2.77
	No control	20	0.67-7.81	4.46
	Calcium chloride	18	2.43-18.2	7.71
	Emulsified asphalt	16	4.73-25.2	13.84
	Acrylic	12	3.19-13.0	7.28
	Lignon	20	1.17-16.2	7.14
	Water	12	0.85-12.2	6.22
	No control	39	2.93-37.5	14.69
	Calcium chloride	a	1.49-4.46	3.03
	Biocat	3	1.44-7.79	3.58
	Arco	4	1.46-2.42	1.79
	Lignon	8	0.78-2.76	1.84
	No control	17	1.41-6.84	3.36

[a] 1 = Southern Illinois
2 = Southwestern Wyoming
3 = Northeastern Wyoming
[b] TSP emission factors in units of lb/vmt.

Finally, much of the control efficiency data in the PEDCo/BuMines exhibit anomalous behavior, such as showing increased efficiency over time. It is believed that much of this is due to the fact that control efficiencies were not referenced to dry, uncontrolled emissions. A 1987 update to Section 11.2 of AP-42 demonstrated the regulatory importance of referencing unpaved road efficiency to worst-case conditions.[13]

Besides studies specifically directed toward surface coal mines, other field programs have produced emission factors that are applicable to a wide range of sources at SCMs. Field tests have been conducted on public roads as well as in various industries, including coal-fired power plants, iron and steel plants, stone quarrying, mining, and smelting operations. The results of these tests have been incorporated into "generic" emission factor models.

Section 11.2 of AP-42 presents generic open dust emission factors which can be applied to the following SCM sources

- scraper travel
- material handling activities for topsoil, overburden, and coal
- haul roads for both overburden and coal
- loading and unloading of trucks
- loadout for transit
- general traffic

Note that generic emission factors are available for the four or five most important emission sources identified earlier.

Finally, as part of a recently completed study for the State of Arizona, MRI conducted a critical review of unpaved road emission estimation.[14] The review encompassed the PEDCo/MRI data." Pertinent results from this study are discussed in the next section.

SECTION 4

EMISSION FACTORS FOR USE AT SURFACE COAL MINES

The preceding section described common PM emission sources and past field measurement efforts at SCMs. This section first describes EPA guidance on emission estimation for SCMs and then presents a critical review of available emission factors.

AP-42 EMISSION FACTORS AND PREDICTIVE EQUATIONS

EPA publication AP-42, "Compilation of Air Pollutant Emission Factors," represents official agency guidance on the emission factors to be used for a wide variety of process, open, and mobile emission sources. Section 8.24 of AP-42, entitled "Western Surface Coal Mining," presents numerous predictive equations and single-valued emission factors for use at western SCMs. Figures 7 and 8 reproduce AP-42 Tables 8.24-2 and 8.24-4, respectively.

The western SCM emission factor equations presented for TSP and IP in Figure 7 are, almost without exception, the results from the PEDCo/MRI field study (Tables 4 and 7). Changes since the section was originally prepared in 1983 have (a) revised the equation for blasting and (b) added PM-I 0 scaling factors for use with the IP emission equations. Quality ratings are generally high, with most equations rated "A" (excellent) or "B" (above average).[15]

The single-valued emission factors given in Figure 8 were developed from the data of three field studies: PEDCo/MRI, EDS, and an early screening study performed by PEDCo for EPA Region VIII. That screening study surveyed 12 operations at 5 different mines (denoted by Roman numerals in Table 8.24-4). Although that report presented emission factors, it made no attempt to develop generally applicable emission factors. Quality ratings for the single-valued emission factors are generally low; most factors are rated between "C" (average) and "E" (poor). For many of the sources, the reader is encouraged to use the 'generic" emission factors found in Section 11.2 of AP-42.

Taken together, Figures 7 and 8 represent official EPA guidance on estimating particulate emissions at surface coal mines. Quality ratings are to be decreased one letter grade (e.g., from B to C) if the factors are applied to an eastern mine.[9]

TABLE 8.24-2. EMISSION FACTOR EQUATIONS FOR UNCONTROLLED OPEN DUST SOURCES AT WESTERN SURFACE COAL MINES (ENGLISH UNITS)[a]

Operation	Material	Emissions by particle size range (aerodynamic diameter)[b,c] TSP ≤30 µm	≤15 µm	≤10 µm[d]	≤2.5 µm/TSP[e]	Units	Emission Factor Rating
Blasting	Coal or overburden	$0.0005A^{1.5}$	NA	0.52^{e}	NA	lb/blast	C
Truck loading	Coal	$\frac{1.16}{(M)^{1.2}}$	$\frac{0.119}{(M)^{0.9}}$	[illegible]	0.019	lb/ton	[illegible]
Bulldozing	Coal	$\frac{78.4\ (s)^{1.2}}{(M)^{1.3}}$	$\frac{18.6\ (s)^{1.5}}{(M)^{1.4}}$	0.75	0.022	lb/hr	B
	Overburden	$\frac{5.7\ (s)^{1.2}}{(M)^{1.3}}$	$\frac{1.0\ (s)^{1.5}}{(M)^{1.4}}$	0.75	0.105	lb/hr	B
Dragline	Overburden	$\frac{0.0021\ (d)^{1.1}}{(M)^{0.3}}$	$\frac{0.0021\ (d)^{0.7}}{(M)^{0.3}}$	0.15	0.011	lb/yd^3	B
Scraper (travel model)		$2.1 \times 10^{-5}\ (s)^{1.3}\ (W)^{2.4}$	$6.2 \times 10^{-6}\ (s)^{1.4}\ (W)^{2.5}$	0.60	0.021	lb/VMT	A
Grading		$0.040\ (S)^{2.5}$	$0.051\ (S)^{2.0}$	0.60	0.031	lb/VMT	[illegible]
Vehicle traffic (light/medium duty)		$\frac{5.79}{(M)^{4.0}}$	$\frac{3.72}{(M)^{4.3}}$	0.60	0.040	lb/VMT	B
Haul truck		$0.0067\ (w)^{3.4}\ (L)^{0.2}$	$0.0051\ (w)^{3.5}$	0.60	0.017	lb/VMT	A
Active storage pile (wind erosion and maintenance)	Coal	1.6 u	[illegible]	NA	NA	$\frac{lb}{(acre)(hr)}$	C[f]

[a]Reference 1, except for coal storage pile equation from Reference 4. TSP = total suspended particulate. VMT = vehicle miles traveled. NA = not available.
[b]TSP denotes what is measured by a standard high volume sampler (see Section 11.2).
[c]Symbols for equations:

- A = horizontal area, with blasting depth ≤70 ft. Not for vertical face of a bench
- M = material moisture content (%)
- s = material silt content (%)
- u = wind speed (m/sec)
- d = drop height (ft)
- W = mean vehicle weight (tons)
- S = mean vehicle speed (mph)
- w = mean number of wheels
- L = road surface silt loading (g/m^2)

[d]Multiply the ≤15 µm equation by this fraction to determine emissions.
[e]Multiply the TSP predictive equation by this fraction to determine emissions in the ≤2.5 µm size range.
[f]Rating applicable to Mine Types I, II and IV (see Tables 8.24-5 and 8.24-6).

Figure 7. Copy of AP-42 Table 8.24-2, presenting emission factor equations for SCMs.

TABLE 8.24-b. UNCONTROLLED PARTICULATE EMISSION FACTORS FOR OPEN DUST SOURCES AT WESTERN SURFACE COAL MINES

Source	Material	Mine location[a]	TSP emission factor[b]	Units	Emission Factor Rating
Drilling	Overburden	Any	1.3	lb/hole	B
			0.59	kg/hole	B
	Coal	V	0.22	lb/hole	E
			0.10	kg/hole	E
Topsoil removal by scraper	Topsoil	Any	0.058	lb/T	E
			0.029	kg/Mg	E
		IV	0.44	lb/T	D
			0.22	kg/Mg	D
Overburden replacement	Overburden	Any	0.012	lb/T	C
			0.0060	kg/Mg	C
Truck loading by power shovel (batch drop)[c]	Overburden	V	0.037	lb/T	C
			0.018	kg/Mg	C
Train loading (batch or continuous drop)[c]	Coal	Any	0.028	lb/T	D
			0.014	kg/Mg	D
		III	0.0002	lb/T	D
			0.0001	kg/Mg	D
Bottom dump truck unloading (batch drop)[c]	Overburden	V	0.002	lb/T	E
			0.001	kg/T	E
	Coal	IV	0.027	lb/T	E
			0.014	kg/Mg	E
		III	0.005	lb/T	E
			0.002	kg/Mg	E
		II	0.020	lb/T	E
			0.010	kg/Mg	E
		I	0.014	lb/T	D
			0.0070	kg/Mg	D
		Any	0.066	lb/T	D
			0.033	kg/Mg	D
End dump truck unloading (batch drop)[c]	Coal	V	0.007	lb/T	E
			0.004	kg/Mg	E
Scraper unloading (batch drop)[c]	Topsoil	IV	0.04	lb/T	C
			0.02	kg/Mg	C
Wind erosion of exposed areas	Seeded land, stripped overburden, graded overburden	Any	0.38	$\frac{T}{(acre)(yr)}$	C
			0.85	$\frac{Mg}{(hectare)(yr)}$	C

[a] Roman numerals I through V refer to specific mine locations for which the corresponding emission factors were developed (Reference 4). Tables 8.24-4 and 8.24-5 present characteristics of each of these mines. See text for correct use of these "mine specific" emission factors. The other factors (from Reference 5 except for overburden drilling from Reference 1) can be applied to any western surface coal mine.

[b] Total suspended particulate (TSP) denotes what is measured by a standard high volume sampler (see Section 11.2).

[c] Predictive emission factor equations, which generally provide more accurate estimates of emissions, are presented in Chapter 11.

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Figure 8. Copy of AP-42 Table 8.244, presenting single-valued emissions factor for SCMs.

EVALUATION OF ALTERNATIVE EMISSION FACTORS

In this section, PM emission sources at SCMs are considered one by one, in the same order as Table 3. Emission factors available for each source are then discussed. Strengths and weaknesses of the factors emphasized, and implications for future testing are also discussed.

The emission factors and predictive equations have been assigned numbers for convenience; these are shown in Tables 9 and 10.

Topsoil Related Activities

Removal-The two emission factors identified for this operation (numbers 2.a and 2.b in Table 10) are already included in AP-42. Both factors have low quality ratings; in keeping with the general guidance given in Section 8.24, the value of 0.058 lb/ton is preferred because of fewer restrictions on its use.

All testing has been performed at western SCMs, and the applicability of the factor to eastern mines has not yet been established, However, because topsoil removal tends to be a relatively minor operation in terms of PM emissions—less than 1% of the total—it appears that further characterization of this source is not as critical as for other sources.

Scraper travel--Recall that this was earlier identified as one of the four or five most important emission sources at SCMs. The two emission factors available for this source are:

- the scraper equation (numbers 5.a and 5.b in Table 9) developed during the PEDCo/MRI study and included in Section 8.24
- the general unpaved road emission factor (number 5.c in Table 9) presented in Section 11.2.1 of AP-42

With the exception of an essentially linear dependence on silt content, the models bear little resemblance to one another. In general, the AP-42 emission factor model developed during the PEDCo/MRI study is recommended for use at western surface coal mines,

Note, however, that over the past 15 years numerous investigators have questioned the ability of unpaved road emission factors developed from tests in the eastern United States to adequately predict emissions in the west. A recent field study of unpaved roads in Arizona, however, found no evidence to support contentions that western unpaved travel emissions are Systematically underpredicted.

Table 9. SUMMARY OF **EMISSION** FACTOR EQUATIONS FOR **SCMs**

No.	Source	Material”	Equation/Factor”	Particle size	Units	Reference
1.a	Blasting	c or 0	$961\ A^{0.8}/D^{1.8}M$	TSP	lb/blast	PEDCo/MRI
1.b		c or 0	$0.0005\ A^{1.5}$	TSP	lb/blast	AP-42 § 8.24[c]
2.a	Truck loading	C	$1.16/M^{1.3}$	TSP	lb/ton	PEDCo/MRI
2.b		C	$0.089/M^{0.9}$	PM-10	lb/ton	AP42 § 8.24[d]
2.c		c or 0	$k\ (0.0032)(U/5)^{1.3}/(M/2)^{1.4}$	e	lb/ton	AP42 § 11.2.3
2.d		C	339.6	TSP	lb/workday/acre	Skelly & Loy
3.a	Bulldozing	C	$78.4\ s^{1.2}/M^{1.3}$	TSP	lb/hr	PEDCo/MRI
3.b		C	$14\ s^{1.5}/M^{1.4}$	PM-10	lb/hr	AP-42 § 8.24[d]
3.c		0	$5.7\ s^{1.2}/M^{1.3}$	TSP	lb/hr	PEDCo/MRI
3.d		0	$0.75\ s^{1.5}/M^{1.4}$	PM-10	lb/hr	AP-42 § 8.24[d]
3.e		0	54	TSP	lb/hr	Skelly & Loy
4.a	Dragline	0	$0.0021\ d^{1.1}/M^{0.3}$	TSP	lb/yd^3	PEDCo/MRI
4.b		0	$0.0016\ d^{0.7}/M^{0.3}$	PM-10	lb/yd^3	AP-42 § 8.24[d]
4.c		0	$k(0.0032)(U/5)^{1.3}/(M/2)^{1.4}$	e	lb/ton	AP42 § 11.2.3
5.a	Scrapers in		$2.7 \times 10^{-5}\ s^{1.3}\ W^{2.4}$	TSP	lb/vmt	PEDCo/MRI
5.b	travel mode		$3.7 \times 10^{-6}\ s^{1.4}\ W^{2.5}$	PM-10	lb/vmt	AP-42 § 8.24[d]
5.c			$k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}(\frac{365-P}{365})$	f	lb/vmt	AP-42 § 11.2.1
6.a	Grading		$0.040\ S^{2.5}$	TSP	lb/vmt	PEDCo/MRI
6.b			$0.031\ S^{2.0}$	PM-10	lb/vmt	AP-42 § 8.24[d]
6.c			54	TSP	lb/hr	Skelly and Loy
7.a	General traffic		$5.79/M^{4.0}$	TSP	lb/vmt	PEDCo/MRI
7.b			$1.9/M^{4.3}$	PM-10	lb/vmt	AP-42 § 8.24[d]
7.c			$k(5.9)(s/12)(S/30)(W/3)^{0.7}$	f	lb/vmt	AP-42 § 11.2.1
7.d			$(w/4)^{0.5}(365-p)/365$			
7.e			$4.83(S/45)^{1.50}$	TSP	lb/vmt	Reference 14
			$1.22(S/45)^{1.88}$	PM-10	lb/vmt	Reference 14

(continued)

Table 4 (Continued)

No.	Source	Material[a]	Equation/Factor[b]	Particle size	Units	Reference
8.a	Haul trucks		$0.0067\ w^{3.4}\ L^{0.2}$	TSP	lb/vmt	PEDCo/MRI
8.b			$0.0031\ w^{3.5}$	PM-10	lb/vmt	AP-42 § 8.24[c]
8.c			246.8	TSP	lb/vmt	Skelly and Loy
8.d			$k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}(365-p)/365$	f	lb/vmt	AP-42 § 11.2.1
8.e			22.0	TSP	lb/vmt	TRC/EDS

[a] C-coal, O-overburden, T-topsoil.

[b] Symbols used:

A = area blasted (ft^2)
W = mean vehicle weight (ton)
M = moisture content (%)
S = mean vehicle speed (mph)
D = blasthole depth (ft)
w = mean number of wheels
s = silt content (%)
L = surface silt loading (g/m^2)
U = mean wind speed (mph)
p = mean annual number of days with at least 0.01 in. of precipitation

[c] Factor based on a reexamination of PEDCo/MRI study results.

[d] PM-10 factors based on IP emission factors developed in PEDCo/MRI study.

[e] For SP, k = 0.74; for PM-10, k = 0.35.

For SP, k = 0.80; for PM-10, k = 0.36.

Table 10. AVAILABLE SINGLE-VALUED EMISSION FACTORS FOR SCM OPERATIONS

No.	Source	Material*	TSD emission factor	Units
1.a	Drilling	0	1.3	lb/hole
1.b		c	0.22[b]	lb/hole
2.a	Topsoil removal by scraper	T	0.058	lb/T
2.b		T	0.44[b]	lb/T
3.a	Overburden replacement	0	0.012	lb/T
4.a	Truck loading by power shovel (batch drop)	0	0.037[b]	lb/T
5.a	Train loading (batch or continuous)	C	0.028	lb/T
5.b		C	0.0002[b]	lb/T
6.a	Dump truck unloading (batch)	0	0.002[b]	lb/T
6.b		C	0.027[b]	lb/T
6.c		C	0.005[b]	lb/T
6.d		C	0.020[b]	lb/T
6.e		C	0.01 4[b]	lb/T
6.f		C	0.066	lb/T
6.g		C	0.007[b]	lb/T
7.a	Scraper unloading (batch)	T	0.04[b]	lb/T
8.a	Wind erosion of exposed areas	S	0.38	T/acre-year

[a] O-overburden; C-coal; T-topsoil; S-seeded land, stripped overburden, graded overburden.

[b] Factor restricted to use at certain types of mines (see Roman numerals I through **V** in Figure 8).

In the case of scrapers, however, that question can be turned around to: Do tests conducted at western SCMs tend to adequately predict emissions at eastern mines? Although the applicability of the model to eastern mines has never been empirically demonstrated. the AP-42 model is also generally recommended For eastern mines.

in a larger sense, the AP-42 Section 8.24 emission factor models suffer from a lack of independent test data against which model performance can be assessed. In other words, all available test data were used to develop the emission factor models. As a result, there are no data available to compare measured emission factors against calculated values.

At a minimum, then, a limited field study of not only scraper but all other travel-related emissions at eastern mines is needed to gauge the applicability of the AP-42 emission factors. In the larger sense, however, the collection of independent test data (at both eastern and western mines) is important to assess model performance. The need for independent assessment grows as the relative importance of the emission source increases. Consequently, the theme of independent data will be repeated throughout this report for the four or five most important sources identified earlier.

Materiai handling, storage, and replacement activities-Only one emission factor (number 7.a in Table IO) specifically addressing topsoil handling was found. This factor dates from an early Region VIII screening study'" and is restricted in AP-42 as applicable to SCMs similar to a lignite mine in North Dakota However, 'Table 8.24-4 suggests that the generic material handling predictive equation in Section 11.2.3 (number 2.c or 4.c in Table 9) should result in greater accuracy. The generic equation should also be more applicable to eastern mines. and is recommended for general use.

This source is a relativeiy minor contributor to PM emissions at SCMs and the need for further study is less critical than for other sources.

Overburden Related Activities

Drilling-- in addition to the single-valued emission factors developed during the PEDCo/MRI study (number 1 .a in Table IO), the Skelly & Loy study presents an emission factor for combined D/OR/CL-'"drilling/overburden removal/coal loading" (number 2.d in Table 9). Because the Skelly & Loy value is for combined sources, the single-valued factor (number 1.a) for overburden drilling is recommended. Again, this factor has not been shown to be applicable to eastern mines Drilling Emissions are relativeiy small contributions to total PM emissions at surface mines, and further field study is not considered critically important at this time.

Blasting-Only a TSP emission factor for blasting is available at this time. This equation (number 1 .b in Table 9) is the result of a 1987 reexamination of certain sources in AP-42 Section 8.24 and replaced the earlier expression (number 1 .a in Table 9). The factor has not been shown to be applicable to eastern mines. The contribution of blasting to total PM emissions at surface mines is usually small, so use of a TSP factor to estimate PM-10 emissions should not be overly restrictive. Furthermore, blasting presents formidable logistical difficulties in sampling; consequently, further field study is not recommended at this time.

Removal-For overburden removal without draglines, two emission factors were identified (number 4.a in Table 10 and the combined D/OR/CL emission factor from Skelly & Loy). The Skelly & Loy value is, of course, combined with other sources and is based on removal by front-end loaders instead of power shovels. AP-42 restricts the use of the 0.037 lb/ton to specific mine locations. Again, Table 8.24-4 of AP-42 suggests that the generic material handling predictive equation in Section 11.2.3 (number 2.c in Table 9) should result in greater accuracy. The generic equation should also be more applicable to eastern mines, and is thus recommended for general use.

The AP-42 generic material handling equation was recently updated and the need for further study is not believed to be critical at present.

For dragline mines, there are two potentially available emission factors

- the dragline equation (number 4.b in Table 9) developed during the PEDCo/MRI and included in Section 8.24
- the general material handling emission factor (number 4.c in Table 9) presented in Section 11.2.3 of AP-42

In general, the AP-42 dragline emission factor is recommended for both western and eastern dragline mines. At a minimum, a limited field study is needed to assess the applicability of the emission factor to eastern mines. Because this can be one of the four or five most important PM sources at dragline mines, there is a need for additional field tests (at both eastern **and** western mines) to independently assess model performance.

Haul trucks-No fewer than four forms of emission factors (numbers 8.a through 8.e in Table 9) were found for this source. The interest in this PM source should not be particularly surprising because it is often one of the two most important PM contributors at truck-shovel mines. The two single-valued factors (8.c and 8.e) are not recommended for general use. Thus, the emission factors considered potentially applicable to this source are:

- the haul truck equation (numbers 8.a and 8.b in Table 9) developed during the PEDCO/MRI study and included in Section 8.24

- the general unpaved road emission factor (number 8.d in Table 9) presented in Section 11.2.1 of AP-42

As was the case with scrapers, the two models bear little functional resemblance to one another. The recent Arizona study found that the generic unpaved road equation tends to overpredict haul truck emissions measured at western SCMs.[14] in general, then, the AP-42 Section 8.24 emission factor models developed are recommended for use at both eastern and western surface coal mines.

This recommendation is, however, provisional in that additional independent data are critically needed. That is, while something is known about the unpaved road equation, nothing is known about the performance of the Section 8.24 model when applied either to eastern mines or to independent data from western mines. (Because of problems noted earlier about sampler design, the PEDCo/BuMines study results do not provide reliable data for model validation purposes.) Because overburden and coal haul trucks can account for up to half of the total PM emissions at surface coal mines, independent quantitative assessment of the available models should be an important objective of any future field effort.

At a minimum, then, field study of haul truck emissions at eastern mines should be considered in future field efforts. In addition, collection of independent test data (at both eastern and western mines) is important to provide a gauge of model performance.

Material handling and storage activities--As with topsoil operations, the generic material handling Equation (number 2.c in Table 9) should be more applicable to a broad range of SCMs and is recommended for general use. This source is a relatively minor- contributor to PM emissions at SCMs and the need for further study is less critical than for other sources. Note, however, that overburden tends to have moisture contents outside the range of the generic equation. Some limited testing is suggested to determine the accuracy of the equation in those applications.

Replacement--For truck-shovel operations, this can be a relatively important PM emission source. Only one directly applicable factor (0.012 lb/ton number 3.a in Table 10) was found; this value represents TSP results from western SCMs. In general, emissions from this source should be fairly accurately estimated using the generic material handling equation, which is potentially applicable to a wide range of mines and material characteristics. Because of the importance of this source at truck-shovel mines. further field characterization study is strongly suggested.

Dozer activities-Only the PEDCo/MRI study has tested emissions from dozers at SCMs. The results were combined into the predictive emission equation (numbers 3.a and 3.b in Table 9) presented in Section 8.24. Those models are recommended for both western and eastern mines.

The dozer equations result in emission rates (i.e., lb/hr) rather than emission factors. The use of a rate has hindered application of the equation to other types of particulate sources-most notably, landfills and remediation sites—which may not share the same dozer operating patterns with SCMs.[17]

Because dozers can account for a reasonably important fraction (approximately 1% to 3% each for overburden and coal) of emissions at SCMs, some additional field study is recommended. At a minimum, the applicability of the dozer equation to eastern mines should be addressed. It is recommended that field results be expressed in terms of emission factors (instead of rates) to facilitate transfer of the results to other emission sources.

Coal Activities

Drilling-Material presented earlier in connection with the drilling of overburden is equally applicable here. The single-valued factor for coal drilling (number 1 .b in Table 10) is recommended. Although the factor has not been shown to be applicable to eastern mines, drilling can be expected to be a relatively small contributor to the total PM emission rate. Further field study is not considered critically important at this time.

Blasting-Again, material presented earlier for overburden is equally applicable here. The reexamined TSP equation (number 1.b in Table 9) is recommended. Because of logistical difficulties in sampler deployment, further field study is not recommended at this time.

Coal loading-Two emission factors pertaining specifically to SCMs were identified: the PEDCo/MRI equation presented in AP-42 and the Skelly & Loy combined "D/OR/CL" factor. The Skelly & Loy value is based on a screening study of several simultaneous sources; its general use is not recommended. In addition, the generic materials handling equation is potentially applicable to this source.

The similarity between the models numbered 2.a/2.b, and 2.c ends at their functional dependence on moisture. There is no overlap in the moisture values contained in the data bases supporting the two models; the generic factor is based on tests of dry materials (approximately 0.25% to 5% moisture) while the SCM data base has moisture contents ranging from 6.6% to 38%. Emission factors calculated from the two models can easily differ by an order of magnitude or more.

The difficulty in reliably estimating coal loading emissions should not be particularly surprising because that source exhibited high variability during the test program. The test report noted that coal loading data were more variable than the other data and that uncertainty in predictions is proportionately greater.[6] Over a total 25 tests at three mines, the relative standard deviation (or, coefficient of variation) was 210%, or roughly twice that of any other source tested. At one mine, the mean measured emission factor was an order of magnitude greater than the mean at the other two mines.

The generic materials handling equation (number 2.c in Table 9) was recently reexamined and was found to predict reasonably well TSP emissions from a rotary coal car dumper- at a power plant.[13,18] That factor, on the other hand, is not based on any field tests conducted at SCMs; its applicability to coal loading at mines has not been demonstrated.

In general, it is recommended that an emission factor appropriate to a coal loading operation be based on the moisture content of the coal being loaded. For moisture contents greater than 5%, models labeled as 2.a/2.b in Table 9 are recommended. For coals with lower moisture contents, the model 2.c in the table is suggested. The reader is cautioned that the appropriate input value is surface moisture corm, which can be determined by oven drying for approximately 1.5 hr at 110°C. Longer drying times for coal can result in the loss of bound moisture, yielding an overestimated surface moisture content.

Although coal loading tends to contribute only slightly to the total emissions at SCMs, there is often confusion and/or debate as to appropriate emission factors and input variables (i.e., surface versus bound moisture contents). Furthermore, emissions have been found to vary widely between mine:;. Reexamination of this source is recommended for any future field studies.

Truck haulage—The remarks about further study made in connection with overburden haul trucks are equally applicable here.

Truck unloading-Table 8.24-4 of AP-42 (see Figure 8) provides several factors for coal truck unloading, depending upon the type of truck dump or upon mine type (Roman numerals I through V). The table further suggests that the generic material handling predictive equation in Section 11.2.3 (number 2.c in Table 9) should result in greater accuracy. The generic equation should also be more applicable to eastern mines and is recommended for general use. Recall that the generic equation performed satisfactorily when applied tc independent coal car dumping test data, Truck unloading tends to be a minor contributor to total mine emissions and further field study is not critically needed at this time. However, collection of some field data with higher moisture contents is recommended.

Material handling and storage activities-As with topsoil and overburden operations, the generic material handling equation (number 2.c in Table 9) should be more applicable to a broad range of SCMs and is recommended for any intermediate handling operations. This source is a relatively minor contributor to PM emissions at SCMs and the need for further study is less critical than for other sources.

Dozer activity--Remarks made earlier concerning this source and the need for further study are equally applicable here.

Loadout for train transit-Table 8.24-4 of AP-42 (see Figure 8) provides two factors for train loading. In general, however, the generic material handling predictive equation is recommended. Again, recall that the generic equation (a) should be more applicable to eastern mines and (b) satisfactorily predicted coal car dumping test results.

General Activities

General (medium/light-duty) vehicle travel-Three emission factor equations were identified as applicable for general vehicle travel:

- the general vehicle expressions developed during PEDCo/MRI and included in AP-42 Section 8.24 (numbers ?.a and 7.b in Table 9)
- the generic unpaved road emission factor included in AP-42 Section 11.2.1 (number *7.c* in Table 9)
- recently developed models for light-duty (nominally 4 wheel, 35 to 55 mph, and 2 tons) vehicles on Arizona unpaved roads under dry conditions (numbers 7.d and 7.e in Table 9)

Unlike other travel-related sources under consideration here, independent emissions test data are available to examine the Section 8.24 model. When applied to the independent data from Arizona and Colorado (with average moisture contents around 0.2%), the Section 8.24 model overpredicted by two orders of magnitude. This is at least partially the result of the narrow range of moisture contents (0.9% to 1.7%) in Section 8.24 data base.

As part of the Arizona study, a review of historical data revealed no evidence on the part of the Section 11.2.1 unpaved road model to systematically underpredict emissions from western roads.

Because of the demonstrated weakness of the Section 8.24 model, the following recommendations have been made for estimating emissions from general traffic at SCMs:

1. The 'Arizona-' models (numbers 7.d and 7.e in Table 9) are recommended for light vehicles (less than 3 tons) traveling at least 35 mph on unpaved roads in arid portions of the western United States.

2. For other situations, the generic unpaved road model (number 7.c in Table 9) is recommended.

Because genera! traffic can account for a large portion of the total PM emissions at a SCM, collection of additional field test data (at both eastern and western mines) should be an important objective of any future field effort.

Road grading—Two emission factors were found for this source: the model from the PEDCo/MRI study included in Section 8.24 (numbers 6.a/6.b in Table 9) and the single-valued factor of 54 lb/hr from the Skelly & Loy program (number 6.c in Table 9). The general use of the Section 8.24 model is recommended. Recall that these factors have not been shown to be applicable to eastern mines.

In addition, the generic unpaved road equation from AP-42 Section 11.2.1 has been shown to conservatively overestimate the measured grading emission factors. Because grading typically represents a minor contributor to total PM emissions, the overestimation is probably not overly restrictive. Further field study of grading emissions is not as critical as for other emission sources at present. Any future testing of graders should emphasize eastern mines.

Wind erosion (open areas, storage piles)--Wind erosion of particulate has been recently reexamined, and a new section of AP-42 (Section 11.2.7, Industrial Aggregate Wind Erosion) prepared.[9] Because substantially over half of underlying data are from coal piles at SCMs, and at end-user locations, the need for future field study is not critical at this time. Any future testing should focus on eastern mines.

SECTION 5

SUMMARY AND RECOMMENDATIONS

Table 11 summarizes the results from a review of available field measurements from surface coal mines, and discusses suggested field testing. For each anthropogenic emission source, an emission factor is suggested.

Overall, the recommendations follow the guidelines presented in Section 8.24 of AP-42; the most notable exception is that for general light- to medium-duty traffic. For this source, independent test data allowed an objective evaluation and selection based on the performance of available emission models. For the reader's convenience, recommendations are either shown in boldface or are underlined.

Although a method has been recommended to estimate emissions for each major PM source at SCMs, additional testing should be considered necessary to address major shortcomings in the data base. The following paragraphs present general conclusions and recommendations.

1. Although mines in the east account for half of the coal surface mined in the United States, particulate emission sources at those mines have not been well characterized. In general, eastern surface coal mines are smaller but more numerous than mines west of the Mississippi. Eastern mines have only begun to be considered in terms of not only particulate emissions, but also operating characteristics that affect emission levels.

   There have long been suspicions that emission factors developed from eastern tests underestimate emissions in the west. In the case of SCMs, the question becomes turned around to: Can test results from western SCMs tend to adequately predict emissions at eastern mines? That is, how applicable are the AP-42 Section 8.24 emission factors to the eastern United States? At a minimum, then, some eastern field verification of the AP-42 SCM emission factors is necessary.

2. Applicability to eastern mines notwithstanding, it is unknown how well most of the AP-42 SCM factors perform in a general sense. Essentially all available test data were used in developing the

Table 11. SUMMARY OF RECOMMENDED EMISSION FACTORS AND FUTURE TESTING NEEDS

Source	Recommended emission factor[a]	Comments and recommendations for further field testing[b]
Topsoil—		
Removal	2.a in Table 10	Although the current need for further field testing is not critical, any subsequent field activities should emphasize eastern mines.
Scraper travel	5.a/5.b in Table 9	The applicability of AP-42 emission factor models to eastern mines needs to be investigated. Of greater importance: independent test data (at both eastern and western mines) are critically needed to assess model performance.
Material handling	2.c in Table 10	Generic AP-42 Section 11.2.3 emission factor model was recently updated and is considered equally applicable to eastern and western mines. Surface moisture contents of interest are largely within range in data base underlying the generic emission factor. The need for further study is not considered critical at this time,
Overburden—		
Drilling	1.a in Table 10	Single-valued factor has not been shown to be applicable to eastern mines. Because drilling is a relatively small contributor to overall emissions, further field study is not considered critically important at present. Future testing activities should include eastern mines.

(continued)

Table 11 (Continued)

Source	Recommended emission factor"	Comments and recommendations for further field testing[b]
Blasting	1.b in Table 9	Recommended factor is the result of 1987 reexamination of PEDCo/MRI data. Factor represents TSP only and has not been shown applicable to eastern mines. Although only a TSP value is available, its use is not believed to be overly conservative in overall inventorying process. Field testing for this source poses serious logistical challenges. Because blasting does not provide a large contribution to total emissions, further testing is not recommended at present.
Removal	4.c in Table 9	Generic materials handling emission factor recommended for truck-shovel mines. This model was revised in a recent update to AP-42 Section 11.2 and is considered equally applicable to eastern and western mines. In general, moisture contents of interest are likely to be outside the range in the data base underlying the generic factor. Limited study is recommended.
	4.a/4.b in Table 9	For dragline mines, the equation found in AP-42 Section 8.24 is recommended. At a minimum, a limited field study is needed to assess the applicability of the emission factor to eastern mines. Additional field test data (at both eastern and western mines) would permit independent assessment of model performance.

(continued)

Table 11 (Continued)

Source	Recommended emission factor[a]	Comments and recommendations for further field testing[b]
Haul trucks	8.a/8.b in Table 9	Because overburden and coal haul trucks can account for up to half of the total PM emissions, it is important to have an independent assessment of model performance. Thus, collection of new field data at both eastern and western mines should be an important objective of any future field effort.
Material handling	2.c in Table 10	Generic AP-42 Section 11.2.3 emission factor model was recently updated and is considered equally applicable to eastern and western mines. Moisture values are probably outside the range of the underlying data base, however. Limited field testing recommended, in conjunction with other overburden handling operations.
Dozer activity	4.a/4.b in Table 9	At a minimum, the applicability of the emission model to eastern mines should be field verified. To facilitate the transfer of results, it is recommended that results be expressed as emission factors rather than emission rates.
Replacement	2.c in Table 9	Because of the importance of this source at truck-shovel mines, Further field characterization (at both eastern and western mines) study is strongly suggested.

(continued)

Table 11 (Continued)

Source	Recommended emission factor[a]	Comments and recommendations for further field testing[b]
Coal—		
Drilling	1.b in Table 10	Single-valued factor has not been shown to be applicable to eastern mines. Drilling is a relatively small contributor to overall emissions. Further field study is not considered critically important at this time. Future testing activities should include eastern mines.
Blasting	1.b in Table 9	TSP factor resulted from 1987 reexamination of PEDCo/MRI data. Has not been shown applicable to eastern mines. Although only a TSP value is available, its use is not believed to be overly conservative in overall inventorying process. Very difficult source for field testing. Further testing not recommended at present.
Coal loading	2.a/2.b or 2.c in Table 9	Model 2.a/2.b recommended for surface moisture contents greater than 5%, model 2.c recommended for surface moisture contents less than 5%. Because of confusion and/or debate as to appropriate emission factors and input variables (i.e., surface versus bound moisture contents) and because of high variability between mines, <u>reexamination of this source is recommended in future field studies</u>. This testing could be combined with testing of other handling activities (below).

(continued)

Table 11 (Continued)

Source	Recommended emission factor[a]	Comments and recommendations for further field testing[b]
Haul trucks	8.a/8.b in Table 9	Because overburden and coal haul trucks can account for up to half of the total PM emissions, it is important to have an independent assessment of model performance. Thus collection of new field data at both eastern and western mines should be an important objective of any future field effort.
Unloading	2.c in Table 10	Generic AP-42 Section 11.2.3 emission factor model was recently updated and is considered equally applicable to eastern and western mines. Moisture contents of interest for coal unloading, however, tend to be far greater than those in generic data base. Limited field testing effort, perhaps focused on eastern mines, is recommended.
Material handling	2.c in Table 10	Same as previous comment.
Dozer activity	4.a/4.b in Table 9	At a minimum, the applicability of the emission model to eastern mines should be field verified. To facilitate the transfer of results, it is recommended that results be expressed as emission factors rather than emission rates.

(continued)

Table 11 (Continued)

Source	Recommended emission factor[a]	Comments and recommendations for further field testing[b]
Loadout for transit	**2.c** in Table 10	Same as comment for coal unloading.
General—		
General traffic	7.c or **7.d/7.e** in Table 9	Model 7.d/7.e recommended for light-duty, higher speed traffic in arid portions of the western United States. Because general traffic can account for a large portion of the total PM emissions at a SCM, collection of additional field test data (at both eastern and western mines) should be an important objective of any future field effort. Note that, when applied to independent data, the light- and medium-duty unpaved road emission model in Section 8.24 overpredicted by one or two orders of magnitude.
Road grading	6.a/6.b in Table 9	Generic unpaved road equation will conservatively overestimate the measured grading emission factors, and the overestimation is probably not overly restrictive in developing a mine-wide PM inventory. Further testing is not critical at present. Future testing of graders should emphasize eastern mines.

[a] Emission factors in **bold** differ from general guidelines given in Section 8.24 of AP-42.
[b] Suggested field testing undertined.

Section 8.24 factors. Thus, there are no independent data against which calculated emission factors can be objectively compared. The lack of independent test data represents a limitation on the use of the SCM factors in both eastern **and** western mines.

The need for independent assessment grows as the relative importance of the emission source increases. Consequently, the theme of independent data is repeated throughout Table 11 for the most important (in terms of contribution to total emission levels) sources.

3 Because most SCM field measurements were made during the late 1970s and early 1980s, data generally reflect a particle size range other than PM-10. The PM-1 0 emission factors presented in AP-42 Section 8.24 are actually scaled IP factors, with the scaling based on size data presented for the generic emission factors presented in Section 11.2.

At a minimum, limited field verification of PM-10 emission factors at eastern and western SCMs should be considered necessary.

4 In keeping with the guidance provided in AP-42 Section 8.24, the generic equation of Section 11.2.3 has been recommended for many of the materials handling operations. That equation has been recently updated and has been found to satisfactorily predict TSP emissions from coal dumping operations. Nevertheless, because so many of material handling operations at SCMs involve materials with surface moisture contents outside the range of the Section 11.2.3 factor, Table 11 suggests that additional field testing be conducted.

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